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To the homogeneity range of tris(8hydroxyquinoline)gallium[†]

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A new technique for the analysis of $p_{8-Hq}-T$ diagrams has been developed for the metal-organic phosphor tris(8-hydroxyquinoline)gallium. The detection of mono- and bivariant equilibria within the $p_{8-Hq}-T$ diagram was done using simultaneous measurements of the photoluminescence and reflection spectra of the con-

densed phase under controlled p_{8-Hq} pressure and temperature. Using preparations with purity better

99.9988 wt%, the $S_{i-Gaq_3}S_{j-Gaq_3}V$ and $S_{i-Gaq_3}LV$ equilibria were studied and the corresponding $p_{8-Hq}-T$ diagram was plotted in the 408–665 K temperature range. For the α -Gaq₃, it was demonstrated that changing the

synthesis conditions within the homogeneity range of the phase resulted in change in the cell volume,

chemical activity and electrical properties of crystalline preparation and thin layers deposited due to it.

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Introduction

Organic electronics have made significant progress in the last decade.¹ The most successful results have been achieved in OLED technology. Nowadays, commercially produced OLEDs are ready to dislodge LCDs from many market sectors.² The problem of stability of emission materials has been solved using materials with purity 4N and better. Further improvement of the functional properties of material could be based on fundamental investigations of organic semiconductors in terms of solid state chemistry.

The progress of complex inorganic semiconductors ($A^{II}B^V$, $A^{II}B^{VI}$) is directly associated with non-stoichiometry investigations.³⁻⁵ To date, there is no absolutely reliable information available on non-stoichiometry of some compounds, for example AlN, GaN, InP, but investigations of p_i -T diagrams, which are necessary for a successful study of non-stoichiometry, were conducted way before the non-stoichiometry of GaAs, GaSb, *etc.* was investigated.⁶

In the case of organic semiconductors, the situation is more uncertain. We did not find any information about p_i -Tdiagrams for organic semiconductors in the literature. This may be explained by the different views of organic chemists and material scientists on the nature of chemical compounds. The organic chemists, in general, consider chemical compounds as substances with a fixed chemical formula. But when material scientists deal with a crystalline substance, they know that at T > 0 K the generation of atomic point defects is inevitable due to the thermodynamic laws.⁷ This means that a crystal phase of any chemical compound exists in a range of compositions, which is customarily called the homogeneity range. For most compounds, the homogeneity range is very narrow (from 0.1 to 0.001 mol%), but within this range, the functional properties of the crystal phase could change drastically within the orders of values.

Analysis of the relationship between non-stoichiometry, synthesis conditions and functional properties is a subject of solid state chemistry.⁸ And the first step for the determination of this relationship is obtaining reliable information about the range of synthesis parameters within which one can obtain a single crystalline phase, including polymorphic modifications. Usually, this information is presented in the form of p_i -*T*-*x* diagrams.

Previously, we showed that there are experimental data which make it possible to consider organic semiconductors and, in particular tris(8-hydroxyquinoline)aluminium (Alq₃), as a crystalline phase with a homogeneity range.⁹ Alq₃ is the most studied metal-organic phosphor for OLED and it is used as a green emitting material as well as an electron transport material.¹⁰ Tris(8-hydroxyquinoline)gallium (Gaq₃) is also known as a green emitting material, but its electron transport properties are much better compared to Alq₃.¹⁰ There are a number of studies that make it possible to establish a general dependence of polymorph transformation for Mq₃ (M = Al, Ga, In) on temperature.¹¹⁻¹³ But all these studies have been conducted under different atmospheres, mostly in vacuum and under Ar pressure. So, some uncertainty in data interpretation has always existed.

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Alq₃ experiments⁹ are carried out using a quenching technique at high temperature state. For obtaining the equilibrium data for the p_i -T diagram, the quenching technique has always been a subject of heated debate. So, in the present research we developed a new technique and attempted to study the p_{8-Hq} -T diagram of Gaq₃ under equilibrium conditions at high temperatures and controlled partial pressure of 8-Hq.

Experimental

Synthesis and purification of Gaq₃

Before the synthesis, all reagents were additionally purified and tested by ICP-MS analysis (NEXIon 300D, PerkinElmer Inc.). The synthesis of tris(8-hydroxyquinoline)gallium was conducted in isopropanol (99.993 wt%) at 50 °C and continuous mixing for 1 h. 1.59 g of crystalline $Ga(NO_3)_3 \times 8H_2O$ (99.98 wt%) was added to a stirred warm solution of 1.73 g of 8-hydroxyquinoline (8-Hq, 99.9989 wt%) in 50 ml of isopropanol, which was followed by the addition of 1.5 ml of NH_4OH solution until the pH = 9. The mixture was maintained for 1 h under constant stirring and heating, and then it was cooled and filtered. The separated precipitate was washed with two portions of n-hexane (99.996 wt%). The obtained material was produced as a light yellow powder. In addition, it was purified by vacuum sublimation using a turbo-molecule pump system ($p < 10^{-4}$ Pa). The diffusion pump system provides Gaq₃ purity, which corresponds to that of the product offered by Sigma-Aldrich -99.995 wt% (trace metal basis). While the Gag₃ powder samples purified by turbo molecule vacuum sublimation after conducting the annealing experiments were as pure as 99.9988% (see the ESI,† Table S1, Fig. S1).

Technique for $p_{8-Hq}-T$ diagram plotting

The basics of the p_i -*T* diagram analysis using the scheme of annealing under bi- and monovariant conditions were described in detail by Kroger.⁸



Fig. 1 Scheme of the technique of the $p_{8-Hq}-T$ diagram analysis applied for Mq₃ (M = Al, Ga, In) phosphors using photoluminescence and reflection spectra at high temperatures under a controlled p_{8-Hq} pressure.

We used the following scheme to analyse the p_i -T diagram of Gaq₃ (Fig. 1). A mixture of crystalline Gaq₃ (10–15 mg) and 8-Hq (50–100 mg) was put in a quartz glass ampoule with 3 mm inner diameter and 20 cm tube length. The ampoule was evacuated to 10^{-3} Pa and hermetically sealed. An optical quartz rod 10 cm in length with polished parallel end surfaces was soldered to one end of the ampoule tube. The fiber optics of the spectrometer system were connected to the other quartz rod end surface at RT.

Testing the optical losses by photoluminescent (PL) measurements of ZnS·Sn phosphor showed that the PL intensity decreases \sim 6 times using the quartz glass rod, but the wavelength of the band maximum and the FWHM of the PL spectrum were the same as measured from the open surface ZnS·Sn powder preparation (see the ESI,† Fig. S2).

Considering Gaq₃ as a quazibinary compound having two components, namely, Ga³⁺ as a coordination ion and the ligand ion 8-hydroxiquinoline (8-q⁻), we used the two-temperatures technique for the study of mono- and bivariant equilibriums.⁸ The chemical potential of the 8-q⁻ component in the compound was determined by the partial pressure of 8-Hq. The temperature dependence of $p_{8-Hq} = f(T)$ was previously determined by the Bourdon manometer technique in the 351–540 K temperature range⁹

$$\lg p_{8-\text{Hg}} = -(2963.5 \pm 43.1)/T + (11.3058 \pm 0.09797)$$
 [Pa],

and by the Knudsen effusion cell technique in the 298–351 K temperature range^{14}

$$\lg p_{8-Hq} = -(4666.1)/T + (16.132)$$
 [Pa].

During the ampoule heating in a temperature gradient (see Fig. 1) 8-Hq vaporized from the initial mixture and condensed at the lowest temperature at the "cold" end of the ampoule. This temperature (T_{8-Hq}) determined the p_{8-Hq} in the whole ampoule according to the above equations.

The temperature of Gaq₃ preparation (T_{Gaq_3}) was the highest in the ampoule but 8-Hq pressure supressed the Gaq₃ molecules' vaporization.

We should determine two types of monovariant equilibriums. The first one dealt with polymorphous transformations S_iS_jV where S_i was the solid phase of the i-polymorph and S_j was the solid phase of the j-polymorph. And this S_iS_jV equilibrium was detected using the changes in the maximum of the PL band (Fig. 2 top) and FWHM. We measured the PL spectra using a QE65000 Ocean Optics spectrometer (S2 in Fig. 1) with excitation by a LLS-365 Ocean Optics laser (L2 in Fig. 1) $(\lambda_{ext} = 365 \text{ nm}).$

The second type of monovariant equilibrium was $S_{i-Gaq_3}LV$. We must detect the formation of the first drop of the liquid when the $S_{i-Gaq_3}LV$ equilibrium was attained both at p_{8-Hq} increase at a constant temperature and at temperature rise at a fixed p_{8-Hq} . In the latter case, it would be the start of the analysed $S_{i-Gaq_3}LV$ equilibrium. When the last crystal of Gaq₃ melts, it will be the end of the analysed $S_{i-Gaq_3}LV$ equilibrium.



Fig. 2 PL intensity at $\lambda_{\text{PL}}^{\text{max}}$ (top) and reflection intensity at 500 nm vs. temperature of Gaq₃ under $p_{\text{8-Hq}} = 1002$ Pa.

We assumed that these corresponded to solidus and liquidus temperatures for the quazibinary system of the Gaq₃ chemical compound and 8-Hq.

We proposed that the appearance of liquid drops would change the colour and optical reflection of the analysed heterophase mixture. This effect is used in modern systems for measuring melting points of organic substances.²³ So, we recorded the reflection (RF) spectra using a QE65000 Ocean Optics spectrometer in the wavelength range of 300–800 nm (S1 + L1 in Fig. 1). We observed a strong decrease in reflection intensity at 500 nm at liquid drop formation (Fig. 2 bottom).

In any case, the kinks on the PL and RF spectra (Fig. 2) were associated with the change in the system state due to transition from bivariant to monovariant equilibrium. The appearance of the first liquid drops in the heterophase mixture was determined as a sharp kink at the highest temperature indicated on the formation of the liquid phase.

The accuracy of $S_i S_j V$ temperature determination is ± 3 K while the accuracy of $S_{i-Mq_3}LV$ temperature determination is ± 2 K.

X-ray crystallography of Gaq₃

The powder patterns were measured on a Bruker D8 Advance diffractometer with a LynxEye detector and Ni filter, λ (CuK α) = 1.5418 Å, $\theta/2\theta$ scan from 18° to 120°, 0.01° step size, in Bragg-Brentano geometry, with the sample deposited on a Si plate. About 20% of silicon powder was added to every sample as the internal standard. The powder patterns were refined in the TOPAS 4.2 software.¹⁵ All peaks correspond to the literature structure of α -(*mer*)-tris(8-hydroxyquinoline)gallium.^{12,13} The lattice parameters were refined with the Pawley technique; the lattice parameter of silicon was fixed at 5.431179 Å.

OLED structure manufacturing

The multilayer OLED devices were fabricated by layer-by-layer vacuum thermal sputtering on a glass substrate $(20 \times 30 \times 3)$

mm) with an ITO conducting layer. The deposition rates of each layer were no more than 0.02 nm \times s⁻¹. The device configuration was ITO/MoO₃ (1 nm)/NBP (35 nm)/CPB-Eu(m) complex(10%)/BCP (15 nm)/Alq₃ (Gaq₃)(30 nm)/LiF (1.2 nm)/Al (100 nm). MoO₃ was used as a hole blocking material, which we specially prepared as an extra pure material with controlled non-stoichiometry. TPD (99%, Sigma Aldrich) is known as one of the most efficient hole-transport materials for providing the necessary hole mobility.¹⁶

Results and discussion

p_{8-Hq}-T diagram of Gaq₃

First, we carried out three runs at fixed p_{8-Hq} . In the first experiment, we used sublimated Gaq₃ without any addition of 8-Hq into the ampoule. To prevent Gaq₃ vaporization during annealing, the empty end of the ampoule was overheated compared to the ampoule end during the preparation. By this way, we reproduced conditions of Gaq₃ congruent sublimation. Taking into consideration that Gaq₃ was similar to Alq₃ and generally vaporized in the form of Gaq₃ molecules,¹⁷ we assumed that dissociation of Gaq₃ molecules was no more than 5–10%. This dissociation could not produce an 8-Hq partial pressure higher than 10^{-3} – 10^{-1} Pa in the temperature range of 470–640 K. Otherwise, sputtering of Gaq₃ on a cold substrate at OLED structure making at 10^{-4} Pa will be impossible because of the destruction of the Gaq₃ molecules.

The other two experiments were conducted at 368 and 1002 Pa of 8-Hq partial pressure. We observed the specific changes in PL spectra *vs.* temperature (Fig. 3). Analysing the dependence of $\lambda_{PL}^{max} = f(T)$ we observed the kinks which were attributed to the polymorphous transitions of Gaq₃ (Fig. 4). The existence of the corresponding polymorphs was confirmed by quenching the ampoules and carrying out the XRD analysis of the crystalline phases at RT.

By this way, we succeeded to plot the points on the $p_{8\text{-Hq}}$ -T diagram, which corresponded to the $\mathbf{S_iS_jV}$ equilibriums of polymorph transitions (Fig. 5). We found out that the general view of the polymorph transformation in Gaq₃ was the same as that for the quenching experiments⁹ but the corresponding transition temperatures had the tendency to increase for high temperature transitions. As one can see, the $p_{8\text{-Hq}}$ growth within the α -, δ -, γ -polymorphs results in widening of the temperature range of the polymorphs' existence, an in contrast, we observe a noticeable decrease of the temperature range for the β -phase existence.

We have also determined the boundary of existence of Gaq₃ solid phases' on the p_{8-Hq} -T diagram by determining the points of S_{i-Gaq₃}LV equilibriums in the temperature range 408–665 K. It was found that the maximum 8-Hq partial pressure under which the Gaq₃ stayed solid corresponded to 1.1×10^4 Pa at 604 ± 2 K. Above this pressure, one could fail to obtain Gaq₃ as a crystalline substance.



Structural properties of crystalline α-Gaq₃

To make sure that within the homogeneity range, a polymorph modification could have a different structure depending on the synthesis conditions, we have annealed powdered Gaq₃ under different 8-Hq partial pressures at 540 K (see the circle points in Fig. 5). For all preparations, we got an α -Gaq₃ polymorph, which proved the reliability of the plotted p_{8-Hq} -*T* diagram. The PXRD of these preparations did not show any presence of other polymorphs except α -(*mer*)-Gaq₃, which belongs to the triclinic space group $P\overline{1}$, and the cell parameters were within the accuracy of those described in literature¹⁸ (Table 1).

The crystal lattice parameters were different for all preparations. The cell volumes as an integrated parameter of the crystal lattice were compared (Fig. 6) and its systematic decrease upon p_{8-Hq} increase was established. The given decrease was much more than the determination accuracy for the cell volume. Similar to Alq_3 ,⁹ it was assumed to be a result of the generation of point defects in the crystal lattice. So, for the second metal–organic compound, we observed the dependence of the structure sensitive property, *i.e.* the lattice volume, on synthesis conditions within the homogeneity range of a certain polymorph. It was supposed that the most probable point defects were vacancies in the metal sublattice.⁹ In the case of Gaq₃ we found that the reproducible data were achieved only when the concentration of total



Fig. 4 Maximum of the PL band of Gaq₃ crystalline powder annealed under different p_{8-Hq} vs. temperature.

impurities was less than 3×10^{-3} wt%. This indirectly showed that the maximal point defect concentration is comparable to the value of $(3-5) \times 10^{-3}$ mol%.

For a (quasi-) binary compound at a constant static pressure (*p*), the partial pressure (*p*_i) as a degree of chemical potential and *T* unambiguously determine *x* (composition) which is the conjugate parameter to the chemical potential. Thus, at a constant static pressure, the definite partial pressure and the definite temperature unambiguously determine the composition. One can stabilize the synthesis conditions and obtain the same composition within the homogeneity range. But to determine the real nonstoichiometric concentration of the composition, we must develop a special analytic method. Unfortunately, there is no universal technique for nonstoichiometrical concentration measurements at the concentration level less than 10^{-2} mol%.²⁷

The conditions for the thermodynamic stability of the binary crystalline phase of the chemical compound are described by the expression²⁸

$(\partial \mu_i / \partial x_i)_{P,T} > 0,$

according to which an increase in the chemical potential of the component (μ_i) leads to an increase in its concentration



Fig. 5 $p_{8-Hq}-T$ diagram of Gaq₃: 1 – our data on the S_iLV equilibriums, 2 – our data on the S_iS_jV equilibriums according to the PL measurements, 3 – Gaq₃ maximum melting point.²⁶ The circle points at 540 K correspond to the 8-Hq partial pressures at which the powder preparations were synthesised, quenched and lattice parameters were measured (see Fig. 7).

Table 1 Structure parameters of Gaq₃ powder preparations synthesized at 540 K and at different partial pressures of 8-hydroxyquinoline

Parameter	8-Hq partial pressure, Pa							
	28.8	102	186	347	646	1175	1860	3090
Space group	PĪ	PĪ	ΡĪ	PĪ	PĪ	ΡĪ	PĪ	PĪ
a (Å)	6.2269(12)	6.2300(11)	6.2320(14)	6.2278(11)	6.2265(13)	6.2258(12)	6.2534(12)	6.2038(10)
b (Å)	12.75386(12)	12.7352(12)	12.7244(14)	12.7236(11)	12.7103(12)	12.6839(11)	12.7217(14)	12.6755(10)
c (Å)	14.70339(14)	14.6981(13)	14.7167(12)	14.6848(14)	14.6862(10)	14.6778(11)	14.5773(9)	14.6496(11)
Alpha (°)	109.980(5)	109.932(4)	110.035(6)	109.911(5)	109.896(4)	109.938(6)	110.651(6)	109.737(4)
Beta (°)	88.748(12)	89.077(11)	89.123(13)	89.157(10)	89.030(12)	89.057(11)	88.868(13)	89.908(10)
Gamma (°)	97.99(2)	97.79(3)	97.64(3)	97.82(2)	97.82(3)	97.73(5)	97.45(6)	97.80(5)
Cell volume (Å ³)	1086.3(4)	1085.6(3)	1086.1(5)	1083.2(3)	1082.2(4)	1079.1(4)	1075.6(4)	1073.1(3)

 (x_i) in the phase at a fixed temperature and static pressure. In our case, an increase in p_{8-Hq} leads to an increase in Gavacancy concentrations in the coordination atom sites. The latter is equivalent to an increase in the concentrations of the ligand forming component (8-q) in the crystal structure.

The probable mechanism of defect generation could be as follows. In vapour, the partial dissociation of the 8-Hg molecules to H and 8-q takes place. The dissociation degree could be very small, but according to the thermodynamic laws, dissociation could occur. Otherwise the Gibbs energy of formation of a chemical compound must be as low as $-\infty$.²⁹ The dissociation degree depends on the partial pressure of the ligand: the higher the p_{8-Hq} the higher is the dissociation degree. Thus, when a crystalline structure is formed from a higher dissociated vapour, the crystalline phase of Gaq₃ can be built not only from Gaq₃ molecules, but also from fragments of dissociation-ligand-forming components (8-q). The ligands take their positions in the crystal lattice while the place for the Ga coordination atom could be vacant. In the solid state chemistry of inorganic compounds, it is a common way of vacancy generation.8 In this case, the strength of the crystal lattice field compensates the absence of a coordination atom. Because the total vacancy concentration is very small (~(3–5) × 10^{-3} mol%) there is no need of high energy. Usually, the enthalpy of vacancy formation $(\Delta H_{V_{Ga}})$ is no more than $E_{\rm g}/2$. In the case of Gaq₃ with $E_{\rm g}\sim 3.5$ eV (ref. 2) it means that $\Delta H_{V_{Ga}} \approx$ 1.75 eV. Taking into consideration the maximal vacancy concentration, we need only ~1.2-2.0



Fig. 6 Cell volumes of crystalline powders of α -Gaq₃ synthesized at 540 ± 1 K (•) and α -Alq₃ synthesized at 483 ± 5 K (•) under different $p_{\text{B-Hg.}}$ The circle points' colours correspond to those in Fig. 3.

Joule per Gaq₃ mole of the crystal field energy to stabilize the crystal lattice. We failed to find the Gibbs energy of crystalline Gaq₃ formation in the literature but the estimation using increments gave the value of 290 kJ per mole, which is $\sim 10^5$ times more than that needed for defect crystal lattice stabilization.

Chemical activity of Gaq₃ with different structure perfection

In the case of inorganic crystalline substances, it is known that structure defects generated by deviation from stoichiometry, have different chemical activities.¹⁹ To verify this statement with respect to metal organic compounds, we carried out the experiments by dissolving α -Gaq₃ preparations synthesized at 523 K at different 8-Hq pressures. The preparations were put into two 2 mm depth cylindrical grooves in a glass plate. A drop of CHCl₃ was added to the glass plate and then was moved to the grooves using a 0.2 mm thickness cover glass plate to fully fill the grooves.

We observed the dissolving process using a Stereo Discovery V.12 (Carl Zeiss) microscope. In the preliminary experiments, we found out that the grooves' volume was enough to dissolve Gaq₃ which filled half of the groove. One can see that the preparation synthesized under congruent sublimation conditions (Fig. 7 the left groove) dissolved at a higher rate compared to the preparation synthesized at $p_{8-Hq} = 3 \times 10^{3}$ Pa (Fig. 7 the right groove).

Usually, crystalline phases with higher perfection have lower chemical activity because of the minimal Gibbs energy of formation.²⁰ However, the specific variant of the process depends on the mechanism of the chemical reaction. Earlier, we demonstrated that α -Alq₃ synthesized at 483 K and p_{8-Hq} = 814 Pa under oxidation at room atmosphere had the most stable spectral-luminescent characteristics compared to that obtained at lower 8-Hq partial pressures.²¹ In the case of Alq₃ with the proposed higher concentration of Al-vacancies, it easily forms an Al-O bond upon interaction of Al³⁺ with atmospheric oxygen due to the lower energy of the Al-q bonds than the Al-O bond in Al₂O₃. The probable explanation of the Gaq₃ dissolving process could be as follows. When the crystalline Gaq₃ with the perfect structure dissolves in CHCl₃ we observe successive cleavage of molecules from the crystalline phase and formation of a true solution.



Fig. 7 Photos of Gaq₃ preparations dissolving in CHCl₃. The time in minutes is indicated in the lower right corner. The preparations were synthesised at 523 K at congruent sublimation conditions (left grooves) and at $p_{\text{B-Hg}} = 3 \times 10^3$ Pa (right grooves).

When we try to dissolve Gaq_3 containing Ga-vacancies, the forces of the crystalline field hamper the splitting of whole Gaq_3 molecules and reduce the dissolving rate. We obtain a solution of Gaq_3 molecules and 8-Hq molecules (or 8-q⁻ ions) in CHCl₃ media.



Fig. 8 The dependence of OLED structure brightness vs. current density. The OLED structure of ITO/MoO₃ (1 nm)/NPB(35 nm)/CBP: Eu(III)-complex(10%)(30 nm)/BCP(15 nm)/Mq₃ (30 nm)/LiF(1.2 nm)/Al(100 nm) used the following Mq₃ as electron transport layer material: sublimated Allq₃ (1), sublimated Gaq₃ (2) and Gaq₃ annealed at $p_{8-Hq} =$ 1002 Pa (3). The insertion shows the EL spectrum and photo of the OLED structure.

The electroluminescence properties of OLED structures

To date, Gaq_3 is considered as an efficient electron transport agent. Its mobility and free electron concentration depend on the material structure defects, especially point defects. It was demonstrated that Eu complexes with pyrazole substituted 1,3-diketones bearing fluorinated alkyl groups are promising for building red emitting OLEDs. We checked the application of Gaq₃ prepared at different 8-Hq partial pressures as an electron transport layer (ETL) with the red emission material of Eu(NTA)₃(Bath).²²

As expected, the application of Gaq_3 instead of Alq_3 as ETL resulted in increase of brightness of the produced OLEDs. We found that the OLED structure with Gaq_3 prepared at $p_{8-Hq} = 1000$ Pa showed 30% higher brightness compared to sublimated Gaq_3 (Fig. 8). This means that the control of the defect structure of crystalline Mq_3 provided by the synthesis within the homogeneity limits makes it possible to obtain preparations with the properties most suitable for the OLED technology.

Conclusions

It was experimentally demonstrated that a crystalline compound which belongs to the class of coordination compounds of metals with organic ligands could exist within the homogeneity range.

The developed technique based on the analysis of spectral behaviour including photoluminescence and reflection spectra of metal-organic phosphors within the temperature range from RT to the maximal melting temperature²⁰ under controlled partial pressure of a ligand forming agent allows the construction of the corresponding p_i -T diagram of the luminescent coordination compound of metals with symmetrical organic ligands under the following conditions: a) the complexes must form a stable crystalline phase within the

analysed temperature range; b) the partial pressure of the ligand must be higher than the partial pressure of the complex molecules.

Using the above technique, the $p_{8-Hq}-T$ diagram of tris(8-hydroxyquinoline)gallium was reconstructed, in which the homogeneity ranges of different Gaq₃ polymorphs were plotted. It was also established that the $p_{8-Hq}-T$ diagram of the Gaq₃ metal-organic compound is similar in structure to the $p_{i}-T$ diagrams of classical inorganic semiconductors such as GaAs,²⁴ CdTe,⁵ PbTe.²⁵

For the high pure crystalline α -Gaq₃ it was shown that the lattice parameters, chemical activity, and electrical properties depend upon the synthesis conditions within the homogeneity range. The adjustment of the defect structure of high pure crystalline organic materials is important for further success in the development of the OLED technology.

Conflicts of interest

There are no conflicts to declare.

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